Understanding the Physics of Functional Fibers in the Gastrointestinal Tract: An Evidence-Based Approach to Resolving Enduring Misconceptions about Insoluble and Soluble Fiber

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ABSTRACT

Enduring misconceptions about the physical effects of fiber in the gut have led to misunderstandings about the health benefits attributable to insoluble and soluble fiber. This review will focus on isolated functional fibers (eg, fiber supplements) whose effects on clinical outcomes have been readily assessed in well-controlled clinical studies. This review will also focus on three health benefits (cholesterol lowering, improved glycemic control, and normalizing stool form [constipation and diarrhea]) for which reproducible evidence of clinical efficacy has been published. In the small bowel, clinically meaningful health benefits (eg, cholesterol lowering and improved glycemic control) are highly correlated with the viscosity of soluble fibers: high viscosity fibers (eg, gel-forming fibers such as b-glucan, psyllium, and raw guar gum) exhibit a significant effect on cholesterol lowering and improved glycemic control, whereas nonviscous soluble fibers (eg, inulin, fructooligosaccharides, and wheat dextrin) and insoluble fibers (eg, wheat bran) do not provide these viscosity-dependent health benefits. In the large bowel, there are only two mechanisms that drive a laxative effect: large/coarse insoluble fiber particles (eg, wheat bran) mechanically irritate the gut mucosa stimulating water and mucous secretion, and the high water-holding capacity of gel-forming soluble fiber (eg, psyllium) resists dehydration. Both mechanisms require that the fiber resist fermentation and remain relatively intact throughout the large bowel (ie, the fiber must be present in stool), and both mechanisms lead to increased stool water content, resulting in bulky/soft/easy-to-pass stools. Soluble fermentable fibers (eg, inulin, fructooligosaccharide, and wheat dextrin) do not provide a laxative effect, and some fibers can be constipating (eg, wheat dextrin and fine/smooth insoluble wheat bran particles). When making recommendations for a fiber supplement, it is essential to recognize which fibers possess the physical characteristics required to provide a beneficial health effect, and which fiber supplements are supported by reproducible, rigorous evidence of one or more clinically meaningful health benefits.

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these studies. Further, attributing the specific beneficial effects to the dietary fiber component of whole foods, as opposed to the effects of other health-promoting constituents, is a daunting task. This review will focus on the beneficial effects of the isolated functional fibers found in fiber supplements, which are readily assessed for efficacy and mechanism of action in well-controlled, randomized clinical trials (RCTs). The review will provide an objective assessment of the totality of evidence from RCTs on three health benefits for which reproducible evidence of clinical efficacy have been published: lowering elevated serum cholesterol concentrations, improving glycemic control, and normalizing stool form in constipation and diarrhea.

METHODOLOGICAL
A comprehensive literature review was conducted with the use of the Scopus and PubMed scientific databases, without limits to year of publication (latest date included: July 9, 2016). Key search words included: fiber, inulin, dextrin, wheat dextrin, resistant maltodextrin, guar gum, oat, oat bran, b-glucan, barley, psyllium, ispaghula, polydextrose, soluble corn fiber, methylcellulose, fructooligosaccharide, galactooligosaccharide, oligofructose, lactation, laxative, constipation, stool, water content, bran, wheat bran, soluble, insoluble, cholesterol, glycemic, blood glucose, and post-prandial. Published clinical studies were identified, and assessed for study design, study population, and fiber dose. The reference section of each identified publication was also searched for any studies that might have been missed in the database searches.

Professional recommendations are ideally based on rigorous, reproducible clinical data, so only those studies that were randomized to treatment, and assessed treatment effects vs a concurrent (parallel or crossover) control group (eg, placebo) were considered for inclusion in this review. Sequential studies that assessed a change from baseline in a metabolic risk factor were not included in the review because they do not account for period effects (a placebo treatment was randomized to treatment, and assessed treatment effect were mixed, but the studies they cited showed a single positive effect on one lipid (ie, triacylglycerol) without acknowledging that the same studies failed to show a significant difference for total cholesterol and LDL cholesterol.79,11 A review of the available published literature yielded 17 randomized, well-controlled clinical studies that assessed the effects of soluble nonviscous, fermentable fibers on blood lipid concentrations, and none of these studies showed a significant difference in total and LDL cholesterol compared with the placebo control (Table 1).9-25 Of these 17 studies, seven were published before 2002 (1997-2000) and were available for consideration in the DRI document.9-12,14,16,23 The additional 10 studies were published after 2002 (2003-2013), representing new information.13,15,17-22,24,25 Of the 16 studies that assessed the triglyceride-lowering effects of soluble nonviscous fermentable fibers, 13 showed no effect of the fiber compared with the placebo on triglyceride levels. It should be noted that if one looks across numerous studies, each with multiple end points assessed for a P value of 0.05, a few of those end points can show a statistically significant difference.

RESULTS
Misconception #1: All Soluble Fibers Lower Elevated Serum Cholesterol Levels
Although it is true that some soluble fibers can effectively lower elevated serum cholesterol concentrations, it is not true that all soluble fibers have this effect. As will be discussed in the following paragraphs, only highly viscous soluble fibers (eg, gel-forming fibers such as b-glucan, psyllium, and raw guar gum) have been shown to exhibit this viscosity-dependent health benefit. Isolated functional fibers have unique characteristics based on the way in which the polymer sugar chains interact with one another (eg, highly branched vs straight chains).7 Highly branched, bush-like polymers with multiple branches at irregular intervals do not pack in a regular array, have no significant effect on viscosity, and are referred to as nonviscous (eg, inulin, fructooligosaccharides, and wheat dextrin). In contrast, straight-chain or linear polymers can pack into a regular array, and the longer the straight chain, the greater the effect on viscosity (see the Figure). A linear polymer in which the adjacent chains form cross-links can form a gel (eg, b-glucan, psyllium, and raw guar gum) (see the Figure).

It has been hypothesized that soluble, nonviscous, fermentable fibers (eg, inulin, fructooligosaccharides), also referred to as prebiotics, can normalize blood lipid concentrations via the byproducts of fermentation.1 Although lipid-lowering effects for inulin and oligofructose have been observed in rodents, the fiber dose administered in these studies was very high (50 to 200 g/kg body weight per day).6 To put this in perspective, a comparable dose for a 75-kg person would be 3,750 to 15,000 g (3.7 to 15 kg) of readily fermented fiber per day, several orders of magnitude above a reasonable/tolerable dose. The 2002 Dietary Reference Intake (DRI) guidelines for fiber suggest that fermentable inulin and oligofructose could normalize blood lipid concentrations.1 The DRI authors did acknowledge that the results for this health effect were mixed, but the studies they cited showed a single positive effect on one lipid (ie, triacylglycerol) without acknowledging that the same studies failed to show a significant difference for total cholesterol and LDL cholesterol.79,11 A review of the available published literature yielded 17 randomized, well-controlled clinical studies that assessed the effects of soluble nonviscous, fermentable fibers on blood lipid concentrations, and none of these studies showed a significant difference in total and LDL cholesterol compared with the placebo control (Table 1).9-25 Of these 17 studies, seven were published before 2002 (1997-2000) and were available for consideration in the DRI document.9-12,14,16,23 The additional 10 studies were published after 2002 (2003-2013), representing new information.13,15,17-22,24,25 Of the 16 studies that assessed the triglyceride-lowering effects of soluble nonviscous fermentable fibers, 13 showed no effect of the fiber compared with the placebo on triglyceride levels. It should be noted that if one looks across numerous studies, each with multiple end points assessed for a P value of 0.05, a few of those end points can show a statistically significant difference.

![Figure](https://example.com/figure.png)

**Figure.** Viscous and gel-forming linear polymers. Drawings represent viscous linear polymers (top) and gel-forming linear polymers (bottom).
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